JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOLUME 33 JUNE 15, 1943 No. 6

ECOLOGY.—*Progress in utilization standards for western ranges.*[1] R. S. CAMPBELL, U. S. Forest Service. (Communicated by W. R. CHAPLINE.)

Range utilization is essential to the welfare of the West and of the United States as a whole. The western range territory provides one-third of the cattle and calves, two-thirds of the sheep, and three-fourths of the wool and mohair grown in the United States. These livestock products are important even in ordinary times. They are indispensable during war. Because of the huge armed force, millions of war workers at strenuous toil, and lend-lease aid to the Allies, the country each year is using double its domestic wool production, and civilian meat consumption has been cut by more than one-third in order to balance consumption with supply.

Within the western range territory the animals producing these requisite supplies graze part or all of the year on range forage —on the grasses, other herbs, and shrubs growing in a generally rather thin stand on land best suited to use by domestic livestock. The area devoted to this use is about 728,000,000 acres, nearly two-fifths of the entire United States. The harvesting of the edible portions of this plant growth each year requires careful management to prevent excessive damage to the range resource and to permit sustained production of forage and livestock.

Range management is the regulation, direction, and control of grazing with the object of the fullest possible use of the forage resource consistent with other range land uses. Man's main control is over the livestock; hence the four principal features of range management are: the most appropriate kind of animals, correct seasonal use, even distribution of grazing, and proper numbers of livestock. The other three features of management are most effective only when numbers of livestock are correct —thus indicating the importance of proper utilization of the range forage each year.

Utilization standards is a term employed to designate a wide variety of information needed by the range manager in understanding and currently judging the utilization and the relative condition or productivity of the range. Utilization is a complex problem, dealing with hundreds of valuable forage plants of several life forms growing on ranges from the high rainfall mountain lands down to low value semidesert shrub areas. Involved are several stages of plant succession, considerable differences between species as to the relish with which they are eaten by livestock at different seasons, resistance to grazing and processes of growth, maintenance, and reproduction. In fact, the whole field of range plant and animal ecology is involved. The job in range utilization standards is to work out answers to some of the more pressing problems of forage utilization by livestock, to take advantage of findings from other pertinent studies, and to formulate the essential results into simple, readily applicable facts for use by busy range administrators and managers. The purpose of this paper is to describe some of the recent advances in this field.

A considerable body of range management information, much of it relating to utilization, has been accumulated during

[1] Paper delivered upon receipt of award for distinguished service in the biological sciences at the 318th meeting of the Washington Academy of Sciences, March 18, 1943. Received March 27, 1943.

the past few decades. The U. S. Department of Agriculture has been interested in range problems since its establishment in 1862, and early-day studies of forage plants, reseeding, and grazing brought together helpful facts on the nature and extent of the resource. National-forest range-management studies, begun in 1907 by James T. Jardine (1910) and A. W. Sampson (1909), in cooperation with F. V. Coville, of the Bureau of Plant Industry, gradually brought together biological facts on the grazing habits and forage requirements of range sheep and cattle, and the growth and use of range forage. These early studies, including both the range vegetation and livestock grazing, led quickly into practical management features such as the bedding out system of handling sheep, water development, correct seasonal grazing, deferred and rotation grazing, and forage inventory through range surveys.

Increasing attention was given the problem of forage utilization until in 1936 a special project was started, primarily to develop improved utilization standards for application on the 87,000,000 acres of national-forest range (Campbell, 1937). It was undertaken by the Division of Range Research and the six western forest and range experiment stations and administrative regions. The immediate job was to evaluate all pertinent data and formulate the best possible standards, mainly in handbook form, for immediate use. At the same time the whole utilization problem was carefully analyzed for the most urgent questions. By 1939, the project turned toward research primarily ecological. The work aimed at these important problems was seriously restricted by limited funds. This work was only in its initial stages when wartime demands for livestock products dictated an immediate program to furnish the best available standards to help both public and private agencies attain maximum sustained production.

The subject of utilization standards can best be presented under two broad headings: (1) range condition, including changes and trends in condition; and (2) range utilization, including methods of measurement and the determination of proper utilization.

RANGE CONDITION

Range condition is the relative state of health or productivity of the range, including both the soil and the forage, in relation to its potential state and the best practicable management. The inclusion of information on range condition in utilization standards requires answers to such basic questions as the following:

1. What are the main range types for which utilization standards are needed?
2. What should be the objective toward which management of each type should aim (in terms of plant cover and soil condition)?
3. What annual or seasonal variations are there in habitat and plant cover that can be recognized in the field?

The answers to these questions draw on practically all phases of range ecology, from vegetation surveys to studies of plant competition and succession. Broad vegetation types include the tall grass, shortgrass, Pacific bunchgrass, semidesert grass, sagebrush, etc., within which are important subtypes requiring individual consideration. Thus, within the open forest type are such important subtypes as the ponderosa pine bunchgrass, the alpine grassland, aspen-fir, mountain brush, and others.

The early studies of Sampson (1919) on plant succession in relation to range management furnished a working method of setting up the objective toward which management should aim on a specific type. He identified four vegetation types or stages that feature plant succession from a depleted condition on subalpine grasslands in central Utah; (1) early-maturing annuals growing on gravelly loam poor in organic matter and moisture; (2) perennial herbs, on soil containing moderate amounts of organic matter and moisture; (3) aggressive perennial grasses with herbs and shrubs on soil with still better organic and moisture content; and (4) deep-rooted or densely tufted perennial grasses on fine soil high in organic matter and available moisture. Sampson determined that overgrazing caused retrogression by destroying the ground cover and allowing loss of soil fertility. He also found that grassland in climax condition furnishes abundant forage, withstands grazing better, and has more

stable soil than when it is in the lower developmental stages.

More recently Pickford and Reid (1942), working on subalpine grasslands in northeastern Oregon, identified stages similar to those of Sampson. They found that the climax stage is characterized by stable, fertile soil, ample desirable forage, and uniform, silt-free streamflow. Green fescue (*Festuca viridula*) is dominant, covering at least half the ground surface.

Subalpine ranges in the mixed grass and weed stage are in only fair condition, since they produce less than the maximum amount of forage and their watershed values are impaired. They have an open stand of vegetation that rarely covers more than one-third of the ground surface. Subclimax grasses are abundant and compete successfully with better forage species for available soil moisture. Weeds are common and accelerated erosion is conspicuous on exposed soil surfaces and pedestaled fescue tussocks.

A still poorer condition is represented by the second weed stage, in which the stand of vegetation is very open and green fescue is represented only by scant remnant plants. Low value weeds and shrubs are abundant, and the soil is clearly eroded, with deep gullies on hillsides and cut channels.

The importance of maintaining ranges in good condition is shown by the grazing capacity of the various stages. Grazing capacity of the near climax green fescue stage, having good soil condition, was more than four times that of ranges in the poor condition represented by lower stages.

Similar stages and corresponding grazing values have been worked out in greater or less detail for several other important types or subtypes throughout the West.

TREND OF RANGE CONDITION

The range manager must know whether his management is bettering the condition and increasing the forage production of his range, or causing it to go on the downgrade. Range trend is the direction and amount of change in range condition. Much of the range land of the West is in some stage of depletion, varying from slight to very severe. The problem of first importance on these deteriorated ranges is to stop the retrogression and start the process of improvement. With the widely varying degree of deterioration of vegetation and soil on different ranges, the determination of range trend is not simple. Improvement or deterioration can be recognized from such features as the vigor of the principal forage species, the species reproducing and becoming established, and character of soil erosion. But it requires extraordinary alertness and ingenuity in the field of dynamic ecology to detect incipient changes and particularly to interpret the natural changes due to variable weather, and to evaluate such changes along with those caused by livestock grazing. For example, broom snakeweed (*Gutierrezia sarothrae*) is a low-growing aggressive shrub with little or no forage value. It has been shown that the occurrence of a dense stand of young thrifty snakeweed plants on range where the palatable black grama (*Bouteloua eriopoda*) has been weakened by overgrazing, represents a definite downward trend (Campbell and Bomberger, 1934). Both the snakeweed and the black grama may be injured by drought, but through careful utilization of the valuable grass, deterioration can be stopped, and at this stage recovery need not be difficult nor require more than a few years.

On the other hand, the invasion of a dense stand of snakeweed on a badly depleted, wind-blown, honey-mesquite (*Prosopis glandulosa*), sand-dune type represents a definite upward trend through stabilizing and building up the soil and affording protection for better forage plants ultimately to grow. Ranges that have reached this low ebb of productivity require many decades to restore a grass stand of reasonably good productivity. However, the occurrence of dense stands of such low value plants as snakeweed is not the final criterion of range condition—it is only one of many important features that must be interpreted in the aggregate.

Advanced deterioration is rather easily recognized by the thin stand of perennial grasses and obviously accelerated erosion, but the early symptoms of deterioration are more difficult to detect. Some of the more

striking signs of a deteriorating range developed to date include: (1) weakened vitality of the important forage plants, as shown by sickly color and reduced height and volume; (2) thinning of the perennial grass cover as indicated by accelerated dying out and disintegrating of tufts; (3) replacement of good forage plants with poor ones, as indicated by abundance of young inferior plants; and (4) accelerating erosion, as evidenced by soil washing on slopes, a distinct increase in number of recent small pencil or finger gullies, and failure of vegetation to grow in small gullies.

In general, an upward trend is indicated by:

1. Arresting of accelerated erosion, perennial vegetation established on eroded banks of drainage channels, no exposed grass roots, soil pedestals with sloping rather than vertical sides, and root crowns of perennial grasses not buried with silt, etc.
2. Vigorous appearance of the stand of forage plants.
3. Noticeable reproduction or spread of plants of the next higher succession stage.
4. Exposed mineral soil colonized with young plants of perennial species.

These and other indicators have been worked out more specifically for several types in the West, but a great deal more remains to be done, both on other types and on more accurate and reliable indicators of range trend.

FACTORS INFLUENCING UTILIZATION

A thorough knowledge of forage utilization is essential because livestock grazing is a major influence in causing the great differences in values between ranges in good and poor condition. Among the important factors influencing forage utilization are the kind and number of livestock; their eating habits; their forage preferences involving succulence, taste, and other qualities of the forage plants; the season of use, the plant composition, and the distribution of livestock over the range.

As to kind of livestock, cattle generally prefer grasses and shrubs, and horses choose grass, while sheep and goats prefer weeds and browse plants, although all animals like some variety in their diet. Soil disturbance through trampling also varies with the animals and particularly with their handling. Thus, poor herding of sheep in compact, fast-moving bands can cause serious overutilization and trampling, whereas open herding and gentle handling can utilize most ranges without serious damage.

Season of grazing is very important in securing utilization of plants when they are palatable. For example, in the Southwest tobosa grass (*Hilaria mutica*) is good forage during summer when it is green and succulent, but after that time it becomes so dry and woody that livestock do not graze it willingly. Correct season of grazing is also very important in allowing the main forage plants ample opportunity to grow and reproduce. Craddock and Forsling (1938) found in southern Idaho that the start of growth on sagebrush-grass ranges was far too variable to allow grazing to begin then. They found a minimum variation in the time when perennial grasses reached a 2-inch height growth and recommended beginning grazing at that stage of development so as to assure sufficient available forage for the livestock and to permit the forage growth to keep ahead of the sheep grazing.

The effect of a number of factors on utilization of black grama by cattle is brought out in a 7-year study on several thousand acres of the Jornada Experimental Range in southern New Mexico. By means of multiple regressions applied to nearly 750 measurements, it was found that percent height utilization of black grama varied significantly with intensity of pasture stocking and distance from livestock water (Fig. 1). The average effect of each additional mile from a livestock watering place was a decrease of 10 percent in utilization of black grama, out to a maximum distance studied of 3.5 miles. When black grama in a pasture was fully utilized on the average, it was overutilized out to 2 miles from water. Under moderate or conservative pasture grazing, the grama was grazed too closely only out to half a mile from water, and rather lightly beyond 3 miles. With light pasture use, the black grama was utilized very lightly at 2 miles from water and was

too closely grazed only in the first one-fourth mile from water.

The effect of distance from salt grounds on utilization of black grama was not great —averaging only 1.3 percent utilization per mile. But improved salting in a properly stocked individual pasture increased the utilization of black grama as much as 10 to 15 percent at 3 miles or more from water.

Other factors were also important. There was higher utilization of black grama near the main roads and well-traveled trails. Also black-grama utilization on the average increased 4 percent for each 0.1 decrease in

DETERMINING PROPER UTILIZATION

Research has employed a number of ways to get at proper utilization which is really the heart of utilization standards. The maintenance of black grama on meter quadrats on range grazed to different degrees was measured by Nelson (1934) on the Jornada Experimental Range. On ungrazed plots, there was a considerable change in tuft area, increasing or decreasing from one year to the next in response to the rainfall of the preceding summer. Further, the average density of black grama over a 13-year period under conservative or moderate

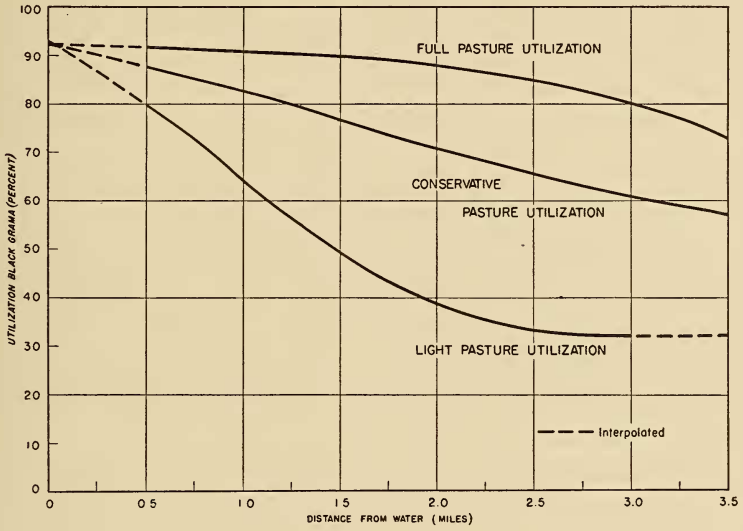

Fig. 1.—Average utilization of black grama by cattle in percent height at different distances from water under full, conservative or moderate, and light pasture utilization, Jornada Experimental Range, southern New Mexico, 1931 to 1937, inclusive.

black grama density after allowing for other factors. Thin stands or scattered plants of black grama were fully utilized out to 3 or 4 miles from water, with only moderate pasture stocking. This brings out the importance of protecting and managing the utilization of the important forage species on depleted types, if they are to be restored to their potential productivity.

Similar studies of important factors influencing utilization on pine bunchgrass range in northern Arizona by Glendening, and on mountain bunchgrass range in central Utah by Clark, are as yet unpublished.

grazing was little different from that under no grazing. Slight overuse of black grama in dry years prevented maximum development of the stand and permitted inferior associated grasses and weeds to secure a foothold on the depleted grama areas. Heavy overgrazing year after year practically killed out the black grama stand and caused very unstable soil conditions. Under moderate grazing, sufficient plant stubble and stolons remained each year to assure good growth and reproduction of the stand the next year.

Persistent clipping of all black grama herbage on plots to a 2-inch height or less

over a 10-year period was found by Canfield (1939) to result in greatly reduced yield and eventually destroyed or killed the plants. In similar studies on clipped tobosa-grass plots, cropping to 2 inches was too close, but clipping to 4 inches maintained a high forage yield and stimulated vegetative reproduction.

Clark, at the Intermountain Forest and Range Experiment Station, working with slender wheatgrass (*Agropyron trachycaulum*) and mountain brome (*Bromus carinatus*) on the Wasatch Plateau in central Utah, has marked individual plants grazed to different degrees and has followed the forage production and utilization through subsequent years. He has noted a tendency for the sheep to come back and graze closely the younger smaller plants each year. This suggests that on some ranges utilization may need to be measured on the younger plants rather than the entire stand, in order to perpetuate the important forage species.

Still another approach to proper utilization was followed by McCarty and Price (1942) who studied the growth and carbohydrate content of important perennial grasses and broadleaf herbs on central Utah mountain ranges. Critical periods in the life cycle were found to be: (1) the active reproductive period from flowerstalk formation through seed ripening, and (2) during the early carbohydrate storage period, when the plant is in a period of recuperation from the reproductive period. A system of rotation grazing in which portions of the range are grazed at a different time each year allows a periodic slackening in the intensity of grazing during these periods in the plants' life processes.

It is not a simple task to express these findings for practical application on the range. One common way is to describe the stubble height that should be left ungrazed for the important forage species. Studies both in the Northwest and in the Southwest show a considerable proportion of ungrazed plants on properly grazed range. Still another way of defining proper use is in percentage of herbage removal.

The difficulty with any statement of proper utilization, whether expressed in stubble height or in percentage removal, is that extreme care is needed in applying it to any area other than where it was developed. Weakened forage plants on deteriorated ranges can not resist the same degree of utilization as thrifty vigorous plants on ranges in good condition. Ordinarily the better forage plants should be grazed less on deteriorated range in order to hasten restoration. Also, they should be used less on steep slopes, particularly on more erosive soils.

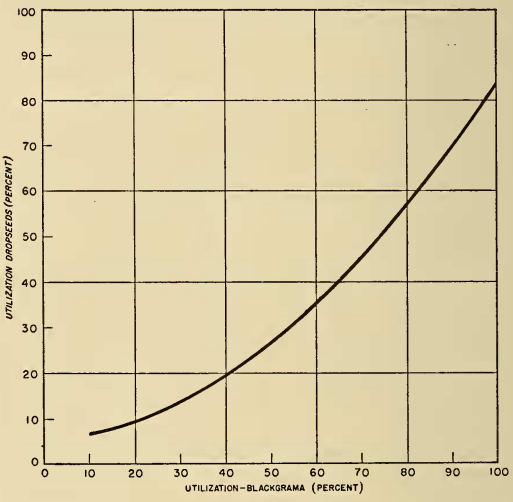

Fig. 2.—Average utilization of sand and mesa dropseeds by cattle at various degrees of utilization of black grama in percent height as determined at the end of the grazing year in June, Jornada Experimental Range, 1931 to 1937, inclusive.

In the final proper use rating, the key forage plants are assigned values mainly on their resistance to grazing, including ability to survive drought and normal competition, and with due allowance for other factors. Less important species are rated at the degree to which they are actually grazed when the key species are properly utilized. This is illustrated in the curve of utilization found between black grama and sand and mesa dropseeds (*Sporobolus cryptandrus* and *S. flexuosus*), less valuable species (Fig. 2). When the black grama was grazed at about 85 percent or proper on this scale, the dropseeds were grazed about 65 percent of their height.

All these results find direct application in the control of livestock grazing on the range. But intelligent control of numbers and distribution of animals on the range requires careful checks of actual forage utilization.

MEASURING RANGE UTILIZATION

Several methods of measuring range utilization have been developed, suited to various purposes and types of vegetation. The most common method now employed by range administrators is the so-called reconnaissance or ocular inspection system, in which the range is systematically examined and the utilization estimated directly, either in descriptive terms or preferably in percentage herbage removal. Frequent close examination of individual plants on small areas a few square feet in size is necessary for reasonable accuracy.

A more accurate way is the ocular estimate by plot method described by Pechanec and Pickford (1937), who tested a number of methods in southern Idaho. The examiner estimates percentage weight removal of herbage from forage species on a series of circular plots each containing 100 square feet. In training, ungrazed vegetation on plots is clipped and weighed, the utilization estimated, then the balance clipped and weighed as a check until the examiner can judge utilization with reasonable accuracy. This method has been found admirably suited for research purposes on grasses, weeds, and browse. Pickford, working in the Northwest, has recently tested the method as an administrative tool on national-forest ranges. Proposed standardized instructions for its application are being considered in the several Western Regions of the Forest Service.

Another method of determining utilization that has found widespread application is the use of grass height-weight or volume tables. The height of grazed stubble is expressed in percent and converted to percentage weight utilization by means of charts or scales showing height-weight relationships of the important forage species. This method is based on the assumption that most grasses have a reasonably constant distribution of weight throughout the plant in relation to height. Three distinct types, all with flower stalks, are indicated in the curves shown in Fig. 3. Bottlebrush squirreltail (*Sitanion hystrix*) has a nearly straight line relationship, with weight distributed about equally through the plant from the top of the tallest flower stalk. Blue grama (*Bouteloua gracilis*) has a gentle curve, with about 80 percent of the weight in the bottom half of the plant owing to the abundance of basal leaves. Sandberg bluegrass (*Poa secunda*) has a slight "S" curve because of heavy seed heads and high concentration of weight in the basal leaves. Curves for plants without seedstalks are still somewhat different. Application of these tables in the field requires great care, because Clark (1943) has found significant differences within the same species in different years and in different altitudinal zones in central Utah.

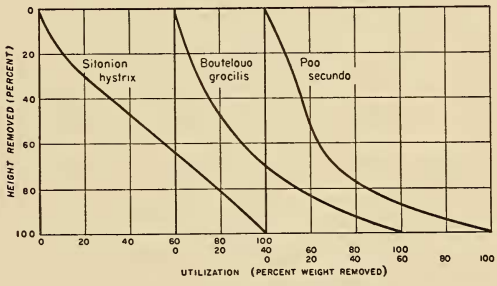

Fig. 3.—Three types of height-weight curves of range grasses, all with seedstalks: bottlebrush squirreltail (*Sitanion hystrix*) from Utah, plants processed by Ira Clark, Intermountain Forest and Range Experiment Station; blue grama (*Bouteloua gracilis*) from Colorado, processed by David F. Costello, Rocky Mountain Forest and Range Experiment Station; and Sandberg bluegrass (*Poa secunda*) from Utah, processed by Ira Clark.

The process of preparing height-weight tables consists of collecting ungrazed plants from the range, then cutting them at one inch or other convenient intervals from top to bottom, weighing the segments and converting this information into percentage height and weight.

Such height-weight tables were prepared for several species in Montana by Lommasson and Jensen (1938); in the Southwest by Crafts (1938); and in Utah by Clark. The original height-weight curves have been used in the field determination of utilization. However, Lommasson and Jensen, and

Crafts independently prepared gauges or "slide-rules" in which to carry the height-weight data in compact form and use it readily. The examiner measures both grazed and ungrazed plants of a selected key species, sets the ungrazed height in the gauge, and opposite the grazed stubble height reads the percentage utilization. In field practice, of course, this procedure requires measuring a representative sample. Reid and Pickford (1941) found that the height-weight and the ocular estimate by plot methods gave substantially the same estimates of utilization on grasses if the stubble height was rather uniform. However, they found the ocular estimate to be simpler in field use.

Still another method of determining range utilization is the measurement of stubble height along a line transect, used in research at the Southwestern Forest and Range Experiment Station (Canfield, 1941).

One final utilization method requiring mention is the visual evaluation of plant residue, developed for application on California annual type ranges (Hormay and Fausett, 1942). Since maintenance of soil fertility and forage productivity on this type depends upon a fairly complete plant cover, the relative amount of debris remaining after grazing is finished each year is judged ocularly. A particularly helpful criterion is the extent to which surface objects such as rodent mounds, pine cones, and sticks are obscured by the remaining vegetation. Systematic observation is, of course, necessary to secure average utilization over large pastures.

Regardless of method of determining utilization, the figure obtained on a range must be compared with a predetermined proper utilization percentage for the important forage species. Also very careful observation of soil erosion, disturbance, and range condition are necessary for an adequate picture of utilization and its effects on the range.

APPLICATION OF RESULTS

Out of all this complexity of factors, plant types, forage species, climatic variation, proper use, and methods of measuring utilization, must come a fairly simplified procedure for application in range management by the stockman and range administrator. One of the first tasks in the Forest Service range utilization study started in 1936 was the assembly of available utilization guides into practical regional handbooks, primarily applicable to national forest ranges. An example is the handbook prepared by Swift and Fausett (1939) for California ranges. After a brief background on range condition, this handbook presents writeups for each of several major types with photographic and text descriptions of the type itself, in good and in poor condition, overutilized and satisfactorily utilized. Research has since brought out several publications embodying useful standards. In addition to several already mentioned, important contributions include Costello (1942) on short-grass ranges of eastern Colorado; Campbell and Crafts (1939) on black-grama ranges; and Crafts and Glendening (1942) on blue-grama ranges of the Southwest. It has also been necessary to standardize and simplify certain concepts such as key areas, key species, and utilization in terms of percentage weight.

As a part of the Department of Agriculture program for sustained livestock production from western ranges, useful range research results have been furnished to range managers generally. Direct assistance has been given the Agricultural Adjustment Agency by preparing and adapting height-weight tables for attaining more efficient use of forage and better management generally on private ranges. Improved procedures have been furnished to range technicians of the Forest Service and other public agencies. Especial emphasis has been given the formulation of better proper use ratings for important forage plants under different sets of conditions. Sound proper use figures for the important forage plants are basic for effective range surveys and the subsequent application of good practices through carefully prepared management plans for range units. Finally a systematic effort has been made to show range managers all through the West that sustained production is obtained only conservative grazing on ranges in good condition.

FUTURE RANGE UTILIZATION RESEARCH

The present period of practical application of utilization standards for maximum wartime production of forage and livestock affords good opportunity to reanalyze the problem so that future research will be pointed at the most urgent features. Among these is a better evaluation of condition and trend to avoid the deterioration that has taken place in the past. A start on work of this sort was made by Ellison and Croft at the Intermountain Forest and Range Experiment Station in 1942, combining range ecology and watershed management viewpoints. A particular weakness is the lack of criteria for judging soil condition. In some instances the vegetation indicated satisfactory condition and trend at the same time that excessive trampling by livestock was causing abnormal erosion. These criteria will include such things as litter, bare soil surface, and top soil remains.

Utilization studies should be extended to additional types and species with special emphasis on deteriorated ranges in order to restore them to maximum productivity as quickly as possible. The effect on forage plants of utilization by big game and rodents is an important field in itself, still largely unexplored. More work along plant physiological lines is needed so that management can be based on a better knowledge of the internal processes of plants on grazed ranges. Gaps in present information are the mechanisms which enable some plants to better survive grazing and drought than others. Likewise, the entire utilization question needs a much better knowledge of ecology, particularly of the important forage plants in relation to the habitat. Finally, related work on nutritive values of forage plants is needed in order to secure the greatest livestock production from range lands in coordination with farm crops and other feed supplies.

LITERATURE CITED

CAMPBELL, R. S. *Problems of measuring forage utilization on western ranges.* Ecology **18**: 528–532. 1937.

——— and BOMBERGER, E. H. *The occurrence of* Gutierrezia sarothrae *on* Bouteloua eriopoda *ranges in southern New Mexico.* Ecology **15**: 49–61. 1934.

——— and CRAFTS, E. C. *How to keep and increase black grama on southwestern ranges.* U. S. Dept. Agr. Leaflet 180, 8 pp. 1939.

CANFIELD, R. H. *The effect of intensity and frequency of clipping on density and yield of black grama and tobosa grass.* U. S. Dept. Agr. Tech. Bull. 681, 32 pp. 1939.

———. *Application of the line interception method in sampling range vegetation.* Journ. For. **39**: 388–394. 1941.

CLARK, IRA. *Suitability of volume-height tables for estimating the degree of range forage utilization.* Journ. For. (In press.)

COSTELLO, D. F. *Maintaining short-grass ranges.* Colorado Ext. Serv. Bull. D. 33, 11 pp. 1942.

CRADDOCK, G. W., and FORSLING, C. L. *The influence of climate and grazing on spring-fall sheep range in southern Idaho.* U. S. Dept. Agr. Tech. Bull. 600, 43 pp. 1938.

CRAFTS, E. C. *Volume-height distribution in range grasses.* Journ. For. **36**: 1182–1185. 1938.

——— and GLENDENING, G. E. *How to graze blue grama on southwestern ranges.* U. S. Dept. Agr. Leaflet 215, 8 pp. 1942.

HORMAY, A. L., and FAUSETT, A. *Standards for judging the degree of forage utilization on California annual-type ranges.* California Forest and Range Exp. Stat. Techn. Note 21, 13 pp. 1942. (Processed.)

JARDINE, J. T. *The pasturage system for handling range sheep.* For. Serv. Circ. 178. 40 pp. 1910.

LOMMASSON, T., and JENSEN, C. *Grass volume tables for determining range utilization.* Science (n.s.) **87**: 444. 1938.

MCCARTY, E. C., and PRICE, R. *Growth and carbohydrate content of important mountain forage plants in central Utah as affected by clipping and grazing.* U. S. Dept. Agr. Tech. Bull. 818, 51 pp. 1942.

NELSON, ENOCH W. *The influence of precipitation and grazing upon black grama grass range.* U. S. Dept. Agr. Tech. Bull. 409, 32 pp. 1934.

PECHANEC, J. F., and PICKFORD, G. D. *A comparison of some methods used in determining percentage utilization of range grasses.* Journ. Agr. Res. **54**: 753–765. 1937.

PICKFORD, G. D., and REID, E. H. *Basis for judging subalpine grassland ranges of Oregon and Washington.* U. S. Dept. Agr. Circ. 655, 38 pp. 1942.

REID, E. H., and PICKFORD, G. D. *A comparison of the ocular-estimate-by-plot and the stubble-height methods of determining percentage utilization of range grasses.* Journ. For. **39**: 935–941. 1941.

SAMPSON, A. W. *Natural revegetation of depleted mountain grazing lands.* For. Serv. Circ. 169, 28 pp. 1909.

———. *Plant succession in relation to range management.* U. S. Dept. Agr. Bull. 791, 76 pp. 1919.

SWIFT, L. W., and FAUSETT, A. *Range utilization standards.* U. S. Forest Service, California Region, 38 pp. 1939. (Processed.)